TECHNOLOGY OF SOUTH INDIAN COINAGE

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Dear Fellow delegates and Friends,

I am beholden to the Executive Council of the South Indian Numismatic Society for the great honour of electing me as the President of the 18th session, which is being held at Kannur, in the gorgeous state of Kerala. I feel privileged to be the President of this conference organized by the Kerala State Department of Archaeology, which was nurtured by stalwarts such as Raj Bahadur Manonmaniam Sundaram Pillai and Shri T.A. Gopinatha Rao.

I intend to present before the august assembly of this session a thematic paper pertaining to the Technology of the South Indian Coinage from ancient times to the dawn of the eighteenth century. I believe that an understanding of the minting techniques, the metallic composition of the coins and the operation of the mints would go a long way in appreciating the coinage of the various dynasties. The enormous interest shown by the south Indian numismatists in recent times, especially in the metallurgical study of the coins, reinforces my belief.

MINTING PROCESS

Surface structure studies made through devices such as scanning electron microscope (SEM) provide us information on the technology used for making the coins[1]. The details of the manufacturing method are also known through the writings such as *Arthasastra* and *Ain-i-Akbari*.

The initial coins found in the southern India are the punchmarked coins. Like in the North, these have been found spread across various regions. They are known through the hoards such as Eyyal (Cochin), Kannian Kuttai (Salem), Pennur and Alampalaiyam (Coimbatore), Mambalam (Chennai), Kayadi (Chingalpet), Chikka-Sindogi (Raichur), Tondaimannattam (North Arcot), Bodinayakanur (Madurai) and Varasingamani (Tirunelveli). They seemed to have been prevalent at least till 2nd Century A.D.

A study of the punchmarked coins show that they were made through two distinct processes. In the first process, the blank used for minting the coin was cast into sheets. Blank or flan or planchet is the term used to refer to the metal (silver in this case) used for making the coin and on which the punches are struck using a die. The blank is cut to the required weight. In order to adjust the weight, edges of the blanks were clipped so that in most cases the blanks became irregular in shape with uneven sides. The sheet may or may not be annealed before the coin-making operations like shearing and punch marking. Annealing is an operation in which the specimen is heated at relatively high temperature, generally more than half of the meting point. The purpose of annealing is to either homogenize the uneven local compositions of the cast structure or to produce a stress free microstructure in case the material is worked (i.e. deformed) beforehand. Shearing is an operation of cutting metal sheet into blanks. The punches (five in the case of Magadh-Mauryan coin series) were placed in succession.

In the second process, the molten metal was poured to form a blank and was struck when in semi-molten stage. It is also possible that the metal-globules were made by drop system[2]. In order to understand the droplet technique, Dilip Rajgor conducted an experiment[3,4]. According to him the droplets can be achieved by two methods. A number of pieces of the required quantity of metal were placed on the dish of cow-dung in a circular path. With the help of blowpipe, the fire from the fire-pot was directed onto each silver piece. This highly concentrated fire will result in the melting of the silver piece and the piece will take the form of a drop. When all the pieces were melted, they were transferred possibly to another person who beat each of them to create a blank. These blanks were transferred to another person who punched the coins with the set of punches (five in the case of Magadh-Mauryan series). Thus we could have an optimized production line for minting the coins. In the second method of producing the droplets, alternate layers of charcoal and silver pieces were placed on a crucible.

The bed of charcoal between layers of silver pieces is required to keep separate the silver layers when the crucible is beaten-up, and the silver pieces needs to equidistant to ensure that the molten drops can be segregated [**Pl.I-1**]. The crucible was transferred into an earthen furnace. In the furnace, the crucible was fully covered with the dishes of cow-dung, and was left to the fire for slow heating. After few hours, silver pieces, in the crucible, get melted and assumed the shape of drops. The silver pieces were passed onto another person who converted them to blanks which was transferred to another who punched the blanks. According to Dilip Rajgor this is an age-old technique used by jewelers.

Coin blanks in many cases were small enough to accommodate all the punches. Thus we see either the punches are partially observed or two or more punches are punched over each other, with the result that the later punches are seen in more detail than the one on which they were punched.

Arthasastra of Kautilya, generally attributed to the Mauryan age, refers to a list of objects used by the counterfeiter of coins (*kutarupakaraka*) [5]. These included metals alkali, crucible, charcoal, bellows, tongs, hammer, chisel, anvil and die engraved with design (*bimba*). It appears that lumps of metal were fired with purifying agents. Then prescribed quantities of purified metal lumps and alloying materials were melted in crucibles and the molten mixed metal was cast into sheets. The sheets or strips from the sheets were cut into pieces of required size and weight. The sheets were blanched with alkali. Then the blanks were placed one after another on the anvil and stamped by the die with the help of a hammer. According to Kautilya, the *Lakshanadhyaksha* (Mint master) should manufacture silver coins with one-fourth part copper and a *masha* of alloy (*vija*) consisting of iron, tin, lead or antimony. In a silver coin of *pana* denomination, weighing 16 *mashas*, only 11 *mashas* were of pure silver[6].

It is surprising that the punchmark method of producing coins prevailed in southern India even till thirteenth century. Gold coins of Eastern Chalukyas,

Chalukyas of Kalyana, Nolambas, Yadavas of Devagiri and Telugu Chodas were produced by punchmarked technique. The silver coins of Yadavas were however minted by die-strike method. The reason for the choice of punchmarked technique to produce the coin (when better methods were available) is still a puzzle.

The second method of minting that was prevalent was through the method of casting. Some of the un-inscribed copper coins from Andhra and North Karnataka were made through this method [**Pl.I-2,3**]. Here a mould is prepared containing the impression of the coin on which molten metal is poured. Gradually hardened, the metal would receive the positive impression of the type found in negative on the mould. Some moulds have been reported (discussed later) and most of them seemed to have been used by counterfeiters.

Singavaram punchmarked coins are cup shaped and were probably made by repousse method[7] [**Pl.I-4,5,6**]. I distinctly remember about two Chola coins being minted by this method [**Pl.I-7,8**]. I had only few minutes to look at these two coins, and it strikes me now that they were also struck through the repousse method. The coins are unifaced. In this method, the thin blank was placed on a metal displaying the positive impression of the device either in high relief or in a sunken state. The thin blank was then hammered to receive on one of its sides the positive impression of the device either in relief or as incised. Consequently the other side of the thin flan got intagliated or raised traces of the device in negative.

The most popular method of minting the coins is the die-strike method. This method of production has been widely used at least since first century A.D. Almost all the gold, silver, copper and lead coins, barring the punch marked gold coins discussed earlier, have been produced by this method. Here the bullion obtained, is smelted and refined to the desired purity or fineness, and then made as blanks of appropriate weight. Ancient Indians had been working metal long before the first coins were struck, and at least by the end of the fifth/fourth century B.C. they were able to extract metals from ores by smelting, to

determine the purity of the refined product, and to make alloys or separate alloys into their constituent parts. To produce blanks of appropriate weight, molten metal was poured into open or two-part closed clay moulds. Experimentation has shown that, with practice, pouring into open moulds or even simply onto a flat surface can be controlled accurately enough to produce blanks within acceptable weight tolerances. Some scholars, however, disagree that such methods would have been used to produce flans for gold or silver coins, and it has been suggested that metal beads or granules of the correct weight were placed in a mould, which was then put into a furnace to melt the granules.

It is most probable that silver and gold blanks were normally cast in individual moulds. Yet often the blanks for bronze coins, and sometimes those for silver, were cast using open or closed moulds in which a number of mould hollows were connected by channels.

Another method used to produce bronze blanks was to pour out a specific weight of bronze in a solid rod or sheet and then to divide it up into a certain number of blanks, either by sawing or chiseling a segment off the rod, or by cutting a section from the sheet. One further step often required before the flan could be struck would be to remove any impurities that may have risen to the top of the flan owing to oxidation during open casting. The flan could have been washed in some form of organic acid or pickle; or the impurities may have been scraped off.

After casting of the coin blank, it can be hammered in cold condition and reheated at a high temperature until complete re-crystallization had taken place (i.e. annealing). A slow cooling then is indicated by some void and cracks from the surface to the inside of the coin.

Striking the coin was a relatively straightforward process. The flan, which was usually hot either from the casting or from reheating, was placed upon the lower die. The punch was positioned over it and hit with a hammer to impress the flan with the types incised on the dies. More

than one hammer blow would have been required to set the image.

In many cases one person could manage the whole striking process alone, first placing the flan on the lower die and then, holding the upper die in place with one hand, wielding the hammer with the other. In this way a modern experimenter was able to strike 100 coins an hour, including casting the blanks. Yet more often, especially in large mints, three or four people were involved. One person would bring the flan from the furnace, another person or possibly two would hold the punch in place by hand or with a tool, a third would wield the hammer, and a fourth would remove the struck coin. Many of the coins, especially those made in copper, show some sloppiness in manufacture, even when carefully cut dies were employed. The coin may be struck off-center or may not receive the complete image of the die because the flan was placed off-center. The flan might move slightly between hammer strokes, causing a slight double-strike. The reverse image may be of uneven depth because the punch was not hit straight on. Plate III - 11A to 11E, shows the process of manufacture of coin through die-strike method.

The relative orientation or alignment of the obverse and reverse images on ancient, medieval and even coins struck till 18th century varied considerably. This is easy to understand, since the two dies were not connected to each other (hinged) and the punch could be rotated freely. A study made on 100 copper coins of Cholas by Kavan Ratnatunga, showed the following distribution of die-axis [8].

Clock	7	8	9	10	11	1	1	2	3	4	5	6
Angle	-150	-120	-90	-60	-30		30	60	90	120	150	180
Coins	5	7	3	7	8	22	11	10	4	5	6	11

Microstructural study can reveal the process of manufacture. A very fine microstructure would indicate a fast cooling process. In contrast, the large grains would indicate that the cooling process was slow. Absence of

deformation in grain structure would indicate that the coins have not been subjected to any mechanical working in cold condition, i.e. below recrystallization temperature. This would indicate that the cast coin blanks were first flattened to the requisite diameter in hot condition that is, above recrystallization temperature of the alloy and then punched immediately in the same hot state. On the other hand deformation indicate that the cast coin blanks were first hammered to the required diameter in cold condition (i.e. below recrystallization temperature), and then subjected to punching. High porosity of coin cross section indicates gas evolution in the casting process.

The operation of Bombay mint during 1794 throws light on the minting technology prevalent at that point in time[9]. The metal is brought to the mint in bars of the size of the little finger, where they are a number of persons seated on the ground provided with scales and weights, a hammer and an instrument between a chisel and a punch, before each man's berth is fixed a stone by way of anvil. The bars are cut into pieces, by guess, and if on weighting any deficiency if found a little particle is punched into the intended rupee if too heavy, a piece is cut off, and so on until the exact quantity remains. These pieces are then taken to a second person, whose whole apparatus consists of a hammer and a stone-anvil and he batters them into something of a round shape about 7/8 inches in diameter, and 1/8 inches thick, where they are ready for impression. The die is composed of two pieces, one inserted firmly into the ground and the other about eight inches is held in the right hand of the operator, who squatting on his heels fills his left hand with the intended coins, which he with inconceivable quickness slips upon the fixed die with his thumb and middle finger, with his forefinger as dexterously removing them when his assistant, a second man with a mall, has given it the impression, which he does as rapidly as he can rise, and strike with the mall on the die held in the right hand of the coiner. The coins are not as large, they do not consequently receive all nor the same impression.

The process of manufacture of hand minted coins, as has been carried out in Hyderabad mint (on the same bases as those at the Delhi mint) is as follows[10]:

1. Blowpipe cupellation assay called in native language *chashni* meaning taste or trial.
2. The melting called *Gudakht*
3. The manufacture of blanks (plain-discs), called *billa sazi*
4. The annealing and blanching called *tab-kashi* i.e. drawing through fire
5. The coining called *sicca sazi*

The mode of manufacture of copper, silver and gold coins is similar.

The remains of Travancore mint (*kammattom*) were discovered by the department of archeology, Kerala[11]. This has thrown light on the manufacture of the coins in the *kammattom*. The silver coins were brought for coining were melted in a *moosa* (clay crucible). When this molten silver is suddenly poured into cold water, it falls into water as grains and dust. This form of silver was weighed to the exact weight of a *chuckram* and separate quantities were thrown into small cavities in a large earthen plate. This plate contains thousands of holes of the exact size of a *chuckram*. This plate with its contents is then put into the furnace for three or four hours. With high temperature the grains of metal are fused and formed into separate globules. There may be 3000 such globules in a single earthen plate. When cooled these globules are taken out and punched by hand into *chuckrums*. One of the dies is usually embedded in a stone and a workman holds the other one. Such type of workman was called *thattan* (gold smith). For making copper cash, copper was purchased in sheets and melted in a similar way. From the early part of the 19th century the coinage of Travancore was more technically advanced. A press with feeding machine for the manufacture of fanam pieces was procured from England.

Coins of gold and silver are said to be coins of intrinsic value, since their worth usually closely approximated the value of the bullion making up the coin. The weight of individual coins of the same denomination

was, therefore, closely monitored. The fineness or purity of the metal used for gold and silver coinages were also closely monitored. In most cases, however, coins of precious metal, certainly those of silver, were somewhat overvalued, somewhat lighter than bullion of equal value would have been. Some overvaluation is to be expected simply to cover the cost of the minting, but it is also clear that in some cases the state minted coins for the purpose of making a profit. In 1953, a hoard of 7668 silver punch marked coins of the imperial type was found in Amaravati in Guntur district of Andhra Pradesh. The hoard was studied by P.L Gupta and found to be belonging to period II-VI. The coins showed variations in weight ranging from 2.6 gm to 3.6 gm with the mean of about 3.3 gm[12]. The copper content of the alloy was not less than 20% copper and went upto as high as 60% [13].

Coins of copper and its alloys, not common until the second/first century B.C., possessed a value that bore little relation to the value of the metal, and thus, like most modern coins, they were a token or fiduciary coins. These coins were highly overvalued in terms of their metal content and were therefore much more profitable for the state to produce. Consequently, less care was given to the weight of individual copper coins and to the purity of the metal or alloy used.

A lot of 100 Rajaraja Chola copper coins probably belonging to a hoard was analysed by Kavan Ratnatunga[14]. The distribution of the measured parameters is shown in **Pl.II-9**. The distribution of the diameter was bimodal and therefore the sample was divided into coins smaller or larger than 17.5 mm. The mean and root-mean-square (rms) dispersion is given in the table [see **Pl.II-9**] for each subset of the sample. The coins with smaller diameter are thicker than the coins with larger diameter but on an average both have the same weight. The graphs [see **Pl.II-10**] show the covariance of the measured parameters. Two different symbols are used to identify coins from the two samples. The table gives the correlation coefficient in each case. The graphs on upper left and right shows respectively that larger and lighter coins are systematically thinner.

The graph on lower right shows however that the diameter of the coins is not correlated with the weight. This independence is unlikely if cold planchets were struck to make these coins.

The conclusion drawn is that the coins were hot-struck from a cooling drop of molten metal. The drops of metal probably had a rms scatter in weight of about 8.5%. The scatter in the force of the strike is independent of the scatter in the weight of the drops of metal. A more forceful strike would spread the molten metal more and make a larger coin. If the diameter of the resulting coin is purely a function of the force of the strike, that would then result in the observed independence of diameter with weight. The resulting thickness of the coin would be correlated with weight and anti-correlated with diameter as expected. Alternatively the cast flans were struck before they cooled. Taken in batches, later ones being cooler from sitting longer, so smaller is their diameter.

Cases of coins counterstruck have been seen. The most known one is the counterstrike on Nahapana's coin by Gautamiputra Satakarni [**Pl.III-12**]. The counterstrike is done to show the overpowering of a ruler. Restrikes have been noticed on the Billama and Singhana gold coins [**Pl.III-13,14**]. They were struck over the Chalukya gold coins. The Barid Shahi rulers restruck Bahmani coins. I have also come across a coin attributed to Venkatapatiraya III, restruck probably by the Barid Shahis [**Pl.III-15**].

Some of the copper coins struck during 17th/18th centuries show mediocrity in minting techniques. In some coins, notably from the Madurai and surrounding areas, the coins exhibit a concave/convex shape. This is possibly due to the reverse die being smaller than flan and the coins were struck in hot state. The reverse on some of these coins (e.g. coins with legend Minatchi, Mamudali, Nababu, Srivira) has feeble legend indicating that they were struck with worn out dies [**Pl.IV-16,17**].

Worn out dies typically exhibit a mushroom effect [**Pl.V-30**]. Some of the coins were struck over an earlier coin and thus show traces of old devices [**Pl.IV-18, 19,20,21**].

METALS, SOURCE AND COMPOSITION

Gold, Silver, Billion, Copper, Bronze, Potin and Lead were the metals used for minting the south Indian coins.

Gold (Au, atomic No. 79, density 19.32 kg/litre, M.Pt. 1063°C) is the most anciently known of metals, occurring as the native metal. Perhaps the most ideal metal for coins, as it is malleable and chemically inert, to the extent that gold coins discovered after long periods in the ground still maintain their lustrous appearance. As it is a soft metal it is generally used alloyed with copper to make it more durable, although gold-silver alloys have also been used.

Silver (Ag, atomic No. 47, density 10.49 kg/litre, M.Pt. 961°C) is an attractive white metal extensively used for coins from ancient times. It is harder than gold, but is easily worked. Unlike gold, it tarnishes readily if there is sulphur in the atmosphere. Billion is an alloy of copper and silver, with more than half copper. In addition to the silver found in gold ores, silver is also found in argentiferous lead ores.

Copper (Cu, atomic No. 29, density 8.96 kg/litre, M.Pt. 1083°C) is a soft reddish metal known since ancient times. It is generally used alloyed in coins although evidence of its pure usage is seen in coins of 17th/18th century especially those minted from Madurai and surrounding areas. Bronze is an alloy of copper and tin, usually 80% to 95% copper. Most 'copper' coins are actually bronze, as pure copper is too soft and rapidly shows extensive wear. While bronze is usually copper coloured, a high tin content will give a silver colour. Potin is an ancient alloy of copper, zinc, lead and tin. Unlike billon, it normally contains no silver, although some alloys containing silver have also been called potin. Potin has been used in some of the south Indian coins (e.g. Satavahanas) during 1st century A.D.

Lead (Pb, atomic No. 82, density 11.36 kg/litre, M.Pt. 327°C) is a very soft bluish-grey metal, and so early lead coins do not survive too well. However, it has been

used for making coins, particularly in southern India during early period as well as by the Dutch during 17th/18th centuries. Lead casts well and has a silvery appearance when new it has often been used for forgeries, especially when plated to replicate gold coins.

As regarding the sources of these metals, gold was imported in the shape of coins by the Roman traders who were generally in need of the commodities produced in the Tamil country[15]. We also have evidence that gold mines were operating at Kolar and Hutti in Karnataka. The Hutti mines are over 2000 years old[16]. The complete absence of indigenous gold coins till about 8th/9th century may indicate the paucity of gold in this part of the country.

The silver found in the ores at Kolar should have also been the source of some of the silver used especially for the punchmarked coins. After the punchmarked coins, the crisis in the availability of silver to support a currency system was felt by the later dynasties. We thus find few dynasties issuing coins in silver and when used they were either debased (e.g. Cholas) or were used in very small quantities in coins (e.g. silver coins of Sevunas, Hoysalas and Vijayanagar).

We see evidence about India receiving or importing silver from outside. It would appear from the Chinese sources that India received silver from China. From the same source we learn that in return for native produce offered by the Chola embassy in 1077, the Chinese emperor gave strings of cash and taels of silver[17].

The principal sources of copper ore are Khetri in Rajashan, Singhbum in Bihar and certain regions of Karnataka like Chitradurga and Kalyadi. The Khetri mines had been worked, more than thousand years ago. An old wooden prop from the Chitradurga mines, which was radiocarbon dated has shown that it is nearly 2000 years old. Although there are no remains of super-structure of old smelting furnaces at Chitradurga and Kalyadi, there are heaps of slag, used tuyers and such other materials. It is likely that the smelting outfit was a hole in the ground with the air being blown by bellows or natural draft[18].

Recent archaeological discoveries of ancient mining sites in Rajasthan indicate that the lead-silver ores in Rajasthan were worked extensively during the successive pre-Mauryan, Mauryan, Sunga and Kushana periods. Extensive mining traditions in the fourth and third century B.C. are recorded in Kautilya's *Arthasastra*. The *Arthasastra* describes the ores of lead, argentiferous galena and silver. It has been stated that the silver for punchmarked coins, bent bars and jewellery at Taxila was obtained by contemporary smelting practice at Ajmer and Zawar[19].

In Periplus of the Erythrean Sea, the logbook of a Greek in Egypt who steered his vessel into Indian ports, it is stated that lead was imported from west into India through Broach and Cranganore.

High-grade ores for large deposits for commercial production are present in three regions. Zawar-Rajpura-Rampura belt in Rajasthan with extensions into adjacent Gujarat, Agnigundala-Bandlamattu-Jangamarajapalli belts in Cuddappah basin in Andhra and Sarigipalli-Dhumohalli area in Orissa. Zawar was mined from 1100-800 B.C. onwards and from where zinc was first produced in the world.

The coins are made out of a certain ore, and the composition of the coin helps in locating the ore used in the manufacture of the coins. The study will also be useful in identifying the modern fakes. Recently numismatists have started showing interest in the study of composition and microstructure.

Several methods/instruments such as Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma and Mass Spectroscopy (ICPMS), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Analysis (EDAX) have been used in the microscopic and metallurgical examination. Specific gravity estimation is a simple nondestructive method, which compares fairly accurately with the chemical analysis by Atomic Absorption Spectrometry (AAS). In recent years, lead isotope analysis has been used to find the provenance of lead. The isotopic composition of lead, that is, the proportion of the stable

isotopes, pb^{204}, pb^{206} and pb^{208} in a given sample had been shown to be directly related to its geological sources. The only serious problem arises if lead from different sources are mixed.

132 punchmarked coins from Koppal (Raichur district) hoard were analysed using wavelength dispersive X-ray fluorescence method. The variations in the silver content were between 51.08% to 94.27% and the copper from 4.75% to 45.92%. Metallic composition revealed the following impurities - iron (0.21% - 038%), lead (0.31% - 1.21%), zinc (0.18% - 0.43%), nickel (0.19% - 0.33%)[20].

Analysis of punchmarked coins from Mambalam hoard indicates that the silver content of the coins is 74.8% and copper content 25.08% [21].

A hoard of 5237 lead coins was found in Anantapur district of Andhra Pradesh. Except two coins, all other coins were of the Horse/arched-hill type [**Pl.IV-22,23**]. Similar coins were found in the Tore-obenahalli hoard[22]. Quantitative chemical analysis and isotope analysis of two coins indicated that they were made from Jangamarajapalli ore[23].

The lead content of the uninscribed coins ranged between 93.58 and 99.21%. The other trace elements were copper, zinc, silver, nickel, cobalt, bismuth, cadmium and antimony[24].

One uninscribed lead coin, four Satavahana lead coins, Jangamarajapalli ore and Bandlamatta ore were subjected to analysis of rare earth elements by ICPMS method. It was found that the uninscribed lead coin rare earth pattern is similar to that of Jangamarajapalli ore. One of the Satavahana coin had high arsenic content (985 PPM) and the four Satavahana coins showed wide variations in their rare earth pattern suggesting that they all came from different ores. They also did not show match either with Jangamarajapalli ore or Bandlamatta ore suggesting that they were made from different ores including the ores imported from west as revealed by the Periplus of the Erythrean Sea[25].

Chemical analysis of ancient lead and copper coins was studied by the ICP-MS method. The lead coins included

Maharathi coins and the copper coins included those of Kotalinga and Satavahana periods. The Kotalinga coin had a high content of cobalt (1736 PPM), silver (798 PPM), bismuth (116 PPM). One of the Satavahana coin had a high content of nickel (3883 PPM). The Satavahana coins exhibited good concentrations of arsenic, and uranium[26].

Seventeen late Roman leaded copper and bronze coins (provenance: Karur) analysed appear to consist of two batches of alloys or coinage. Seven of the analysed coins seem to be of extremely high lead contents with around 26%-40% lead while the remaining ten coins had lower amounts of alloyed lead of 1-17%. Tin appears to be randomly alloyed with 1-8% tin in about six of the coins, with the higher amounts of tin being generally associated with lower amounts of lead in coins.

The micro-structural examination and hardness measurements suggested that the low leaded copper or bronze coins seem to have undergone fairly thorough heat-treatment such as annealing and hot or cold working to improve the toughness and homogeneity by removing cored dendritic remnants, before hot striking. The levels of iron and also sulphur in the Karur coins are low enough to indicate that the alloyed metals underwent some refining, such as perhaps heat treatment, to reduce impurity levels.

Sharada Srinivasan who made the study, inferred that the silver free Karur coins, particularly the high leaded ones may in fact be contemporary forgeries from late Roman mints, with the lead being added as cheaper base metal. Yet another possibility, particularly the exceptionally high leaded coins, may have been produced in local South Indian mints as local imitations of Roman or late Roman coins[27].

One of the coins of Makkotai from Karur revealed that it was counterstruck over a Roman coin [**Pl.V-24**]. Krishnamurthy[28] who brought this to the notice of numismatists concludes that the Makkotai coins were counterstruck on Gaius and Lucius type of Augustus coin (2 B.C. to A.D. 4). This explains the source of the silver in Makkotai coins. The metallic composition of one of the coin analysed indicates the following:

Silver - 96.18%; Copper - 1.49%; Zinc - 1.03%; Nickel - 0.49%; Iron - 0.81%; Lead - traces.

The analysis of Satavahana lead coins available with the British Museum show that the lead used in these coins should have come from the Spanish and Sarinan ore sources. Analysis of two Satavahana lead coins (provenance of one of the coin: Chintalapet, Karimnagar district, AP) by A.B. Avadhanulu[29], showed the presence of Vanadium as a trace element equivalent to 298 ppm and 620 ppm and showed absence of Chromium which appears interesting as Chromium and Vanadium accompany each other in non ferrous ore deposits. Presence of Vanadium was also noticed in three early Pallava coins (provenance: Karur). The three Pallava lead coins showed lead content of 99.06%, 99.07% and 99.68% and Vanadium content of 0.02%, 0.02% and 0.01%. Since Vanadite is found in altered lead deposits in Spain and this country has been a major source of Roman lead and the isotopic studies of Satavahana Coins show that the imported lead has been used for minting the lead coins by Gautamiputra Satakarni (A.D. 54-58) and Vasisthiputra Pulumavi (A.D. 88-116), it can be presumed that Roman lead of Spanish origin was used by the Satavahana kings and the Pallavas who were the subordinates of Satavahanas[30].

A study of four lead coins of Pallava and one lead coin of Satavahana indicated presence of lead as matrix (96.7% to 99.4%) in Pallava coins along with minor/trace elements, which include titanium, vanadium, iron, copper and zinc. The lead content is 99.38% in the Satavahana coin[31].

The spectroscopic study of two Pallava coins showed that one of the coin (Bull-Swastika) was a high tin bronze containing copper around 74% and tin of the order of 18%. Other than these two elements, nickel and iron are in the region of 2% and 5% respectively. Spectroscopic analysis of the second coin (Bull-Conch) indicates that the metal is a high tin bronze with a tin content of 24% and copper 74%. Iron and nickel are found in the order of 1.48% and 0.27% respectively. Metallurgical study indicates that the coins were produced by die forging in the hot condition

after solidification of the casting. They were cooled very fast by quenching in water[32].

The analysis of four copper Pallava coins from Karur indicated presence of tin ranging from 18% to 43.72% indicating strong preference of high-tin bronze to make coins. R. Krishnamurthy who presented the analysis gives the plausible reasons for this as "it was closer imitation of gold than other alloys readily available in the area and that only this particular composition could be fabricated except by casting". The percentage of tin ores in India is insignificant when compared to the Southeast Asian countries like Malaysia, Thailand and China, which yield 80% of the tin of the world. It is thus possible that the tin could have been imported from these areas[33].

Spectroscopic analysis of one of the copper coin of Pallava (provenance not known) indicated that the tin content was around 22% and iron and sulphur are around 1.5% and 0.06% respectively. The presence of a coarse grain structure along with numerous blowholes and pores indicate that the coin was made by casting i.e. by solidification of the molten metal in a mold. It appears that the die forging of the metal with the impression of the figure was carried out at an elevated temperature before the solidified metal has cooled to room temperature. After the die forging, at about 700^0 C, the metal was cooled very fast by water quenching. This was revealed by the presence of martensitic structure in the micrograph[34].

The study of Pallava copper coin[35] show the level of tin varying from 18% to 26%. This study used Spectroscopic meter, Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and Atomic Absorption Spectroscopy (AAS).

Specific Gravity and Spectrometer analysis of a Rajadhiraja gold coin [**Pl.V-25**] indicate very low level of gold content (15.25%)[36].

Study of Bahmani Coins indicate that the copper coins of Muhammad Shah I (A.D. 1358 - 1375) and Alauddin Mujahid Shah (A.D. 1375 - 1378) have high content of lead (12%) compared to the copper coins of other kings suggesting that they have been made of different ore[37].

V. Jeyaraj published[38] chemical composition and microstructure study of five copper coins of the Sangam Pandya, Kongu Chera, Chola, Madurai Nayaks, Pandya **[Pl. V-26 to 29]**. All the coins had high percentage of iron which show that the copper extracted from copper pyrites ($CuFeS_2$) were not purified. The composition of tin and lead in that order were 1.374% and 0.43% (Rajaraja Chola), 1.85%, 3.65% (Sundara Pandya), 3.469% and 3.25% (Sangam Pandya), 10.93% and 3.75% (Kongu Chera), 14.01% and 2.75% (Madurai Nayaks). Tin gives toughness while lead facilitates fluidity. Microstructure study showed that the Pandya and Rajaraja Chola coins have equiaxed polyhedral structure indicating the coins were made of cast flans and either annealed or slowly cooled in a clay-mould.

A study was made on the chemical composition of the copper coins of Arcot Nawabs[39]. The study revealed that the coins had copper content ranging from 99% to 99.9% with very less impurities thus indicating that pure copper was used for minting coins with no deliberate addition of another metal. The edges of the coins were cracked due to the absence of adequate quantity of lead. Metallographic studies of the coins revealed that cast blanks were battered in cold condition while striking with dies. The coins are found to be cup shaped with the obverse being convex and the reverse concave. This indicated that the striking of the upper side of the blank experienced more pressure due to striking with the upper die and the metallic blank (being made of pure copper) didn't exhibit sufficient strength to withstand this pressure.

COIN MOULD AND DIES

Metal dies were used to stamp the types into the flans. Relatively few dies have been found, since official dies were often destroyed so that they could not be used illicitly when they became too worn or when a change in types demanded that new dies be cut. Although iron is harder than bronze, hardened bronze is hard enough to strike even bronze coins, and evidence indicates that

bronze containing a relatively high percentage of tin was the preferred material for dies. Iron dies were also used[40].

Since with images on coins are in relief, the images on the dies are inset and reversed, the negative and mirror images of what is depicted on the coins. It is not clear as to how the dies were made. Two replication processes were feasible. One method would be to cast the dies. The completed design could have been hand engraved for touchup where needed. Alternatively, the die could have been made by master engravers who cut the pattern on the metal using chisel.

Many times great artistry went into the die cutting as can be evidenced from the gold coins of Rashtrakutas, Gangas, Hoysalas, Vijayanagar empire and silver and gold coins of Tipusultan. In striking a coin two dies, an obverse and a reverse, were employed. The obverse or lower die would have been set into an anvil, often a block of wood or stone. The upper, reverse die was loose, and could take a variety of different forms (see examples of the forms of the reverse die in Plate VIII). The type could be cut directly into the end of a short rod, cylinder, or pyramidal piece of metal, but most often the die proper was simply a short segment or disk of bronze inserted into a punch or collar made of iron. The whole punch, with the reverse die attached, was probably three to eight inches long.

From the coins observed it appears that the lower or obverse die was almost always used to stamp the principal face of the coin. It was preferable to carve the deeper and more intricate image into the lower, since it was placed within an anvil and was therefore better protected, wore down less quickly, and suffered less damage than the upper die, which received direct hammer blows during the striking. It should be noted that in general use, the term "obverse" usually designates the principal side of the coin, regardless of whether it was made with the lower die.

The number of coins that could be struck from a die before it had to be replaced varied considerably, owing to a number of factors: metal composition, size of coin, and depth of relief. Smaller dies and dies with shallower relief

lasted longer. Modern experiments suggest that an obverse die could strike about 15,000 acceptable coins, a reverse die only about half as many. Often, however, more than two reverses were used with an obverse die, since dies were often replaced before they wore out. It is likely that dies were also often partially re-cut or altered, both to repair small flaws or cracks that might develop in the die face and to change or add inscriptions.

The lifespan of dies was dependent on the number of coins struck. Dies at smaller mints may have been used for a year. It is likely that in a busy mint, dies had to be changed every day! In one of the *dastaks* belonging to Aurangzeb's reign, it is stated that Surat mint minted 4,000 coins per day. This was increased to about 8,000 coins per day during early 17th century and to about 30,000 per day during later half of the 17th century[41]. Although such details are not available for the southern mints, it is not difficult to extrapolate and draw conclusions.

Let us now look at some of the coin dies and coin moulds reported.

R. Krishnamurthy reported a Roman die[42], which was said to be a surface collection from Amaravathi riverbed in Karur **[Pl.VI-31]**. The die (metal: bronze, diameter: 25 mm, height: 18.3 mm, weight: 74.9 gm) has a portrait of the Roman emperor HADRIAN and a legend HARIANVS AVG. III p.p. Coins with this legend, were issued when Hadrian returned to Rome in A.D.134 and continued to be used till his death in A.D.138. Krishnamurthy concludes that the die could have been imported and used by a clandestine mint for producing Roman coins.

A terracotta coin mould representing the reverse side of the gold coin of Roman emperors Augustus and Tiberius was found during excavations at Talakad[43]. The mould has the figure of Livia sitting on a tall seat holding a scepter in her right hand and a branch of a tree in her left. On the right is the legend MAXIM and to the left is the legend PONTIF. The mould was found very near a kiln **[Pl.VII-38,39]**. On the basis of this, it was concluded that the mould was used by the goldsmith for making

counterfeit Roman gold coins. From stratigraphic position it appears that the mint was used during the period first to third century A.D.

A bronze die 9 mm thick and 20 mm dia, was purchased from Karur and is presently at IIRNS, Nasik[44] **[Pl.VI-32]**. Reverse impressions of three symbols all with circular depression is found. The symbols are sun, six-armed symbol and the dog on arched-hill. This die is similar to the one reported from Eran by Cunningham. Since the various symbols on the punchmarked coins were punched by separate punches and not a die with multiple symbols, this die would have been used for making counterfeit punchmarked coins.

A clay coin mould was found during Veerapuram excavations. The fragment of the mould contained squarish depression of the obverse of two punchmarked coins (symbols?) but details are not clear[45].

A punchmark die (bronze, 2.9 gm, 10 mm x 7 mm, 3 mm thick) was reported from Karur[46]. The die has a bull and a taurine symbol **[Pl.VI-33]**. This is the fourth symbol in the VI.IV.F.145 Magadh-Maurya Karshapana series[47]. This is probably the only punchmark die reported till date.

Four terracotta coin moulds attributable to Pallavas were found during excavations at Kanchipuram. The same site yielded two coin moulds for producing punchmarked coins and five moulds for producing Satavahana coins. The details of the Pallava moulds are as follows **[Pl. VI-34,35]**:

1. 25 mm dia, Bull to left; above indistinct symbols
2. 20 mm dia, Humped bull facing left
3. 16 mm dia, Bull to left
4. 27 mm dia, Bull?

R. Krishnamurthy feels that these moulds were used by ancient counterfeiters[48].

I recently came across a bronze die, which was used for minting the *Viraraya fanams* **[Pl.VI-36]**. The die has the stylized lion device normally found on the *Viraraya fanams* (weight: 25.4 gm, 15 mm diameter, 20 mm height).

A coin die of Asaf Jahi ruler Mir Mahbub Ali Khan was recently reported[49]. The bronze die (weight: 194.8 gm, 27 mm high, 37 mm diameter) carried the legend *Zarb*

Farkhanda Buynad Zalus Maimanat Manus Hyderabad. The die was used to mint the rupee coin [**Pl.VI-37**].

The details of the minting techniques used by Travancore mint, came to light when the department of Archaeology, Kerala discovered the remains of Travancore Kammattam. G. Sarojini Amma reported this important finding[50]. Among the remains were found dies and punches used for minting silver chuckrums and copper kasu. The details of the dies used for making different coins are shown in Appendix A and Plate VIII. From the early part of the 19th century the coinage of Travancore was more technically advanced. A press with feeding machine for the manufacture of fanam pieces was procured from England.

MINTS

There are a number of references to the mints called *akkasalai* in Tamil country in the early times[51]. Earliest reference to *akkasalai* is seen in an inscription dated A.D. 1100[52]. The term *akkam* means coins[53]. In an inscription dated A.D. 1264, reference is made to *akkasalai* and the six communities involved in labour[54]. The term *kammattam* is also found in inscriptions from around eleventh century A.D. and this denotes a mint. In an inscription from Srirangam dated A.D. 1261, belonging to the period of Hoysala Viraramantha, the name of the officer of a mint was referred to as *kammattattu anikkara*. In the inscriptions found in Karnataka, the term *kammatta* is used to denote a mint. In an inscription dated A.D. 1040, the word *kammatta* is seen and the same inscription refers to a process of putting the royal seals and symbols on the coins as *undigeya kammatta*. Two inscriptions from Karnataka dated A.D. 1173 and 1186 refers the name of the person producing a special kind of nail for the purpose of minting coin as *annikkara nagi setti* and *anikkara sankara setti*[55].

During the time of Maratha rulers of Thanjavur, a *kammattam* was allowed to be setup at Nagapattanam. This was already in existence during the time of Nayaks of Thanjavur. In the year A.D. 1676, when the Dutch occupied the port city Nagapattanam, the Maratha king Ekoji,

allowed them to run the mint for minting panam of 3 ½ fineness and another for minting *varagan* gold coin of 8 5/8 fineness. In all probability the Nagapattinam *akkasalai* was in existence for a long time and came under the control of succeeding dynasties and named as *kammattam* the term in vogue at that time.

State mints under Nizam's dominion were operating at Aurangabad, Bidar, Chandore, Dowlatabad, Elichpore. Hyderabad mints were at Sultan Shahi, Surunagar, Asafnagar, and Lalaguda, Indore, Gulbarga, Kalyani (Bidar), Sugoor (Warnaparthi), Tiruamal.

The private mints created under Nizam's dominion before A.D. 1853 operated at Amraoti, Biagupally (Kurnool), Gadwal, Gurumatkal (Gulbarga), Gopalpet, Kalvakurti, Kosa, Malkapur, Narayanpet, Nalkhora, Raichore, Lemerchintga, Wabgaon[56].

The practice of coin alteration by assiduous and enterprising goldsmiths is seen through the inscriptions. During the reign of the Kalyana Chalukya soverign Vikramaditya VI dated A.D. 1096, the officials of Kottidone made an agreement with two persons that the latter convert *Lokki-gadyana* into *Mayura-gadyana* maintaining the same weight and that in consideration of their profit they should pay twelve *gadyanas* to the local temple. Besides the inscriptional evidences revealing the production of coins out of the existing state currency, there are quite a number of foreign travel accounts clearly showing the flourishing profession of minting currency out of bullion. Farishta makes a reference of the coins of Muhammad Shah I Bahmani being melted down out of religious animosity by Hindu bankers at the instigation of the Rajahs of Vijayanagar and Telingana so that only the Hindu currency could be in circulation. Farishta also says that goldsmiths and dealers in bullion were authorized, by prescriptive right, to fabricate money at will on their own account, without being subjected to any attack or control on the part of the ruling power. Goldsmiths were also often money changers and bankers as mentioned by Vasco Da Gama. Barbosa speaks of coins being made in many towns of Vijayanagar kingdom and Varthema speaks very

high of the accuracy and efficiency of the money changers and bankers of Calicut[57].

References to the people operating in the mint are found. *Ain-i-Akbari* provides references to the people operating in the mughal mints. Whenever the bullion, silver, old coins or copper was received at the mint to be coined, the *darogha* along with the *amin*, the *mushrif*, the *tahwildar*, the *quanungo* and the *sarraf* examined the quality and quantity of the metal and got it weighed. A receipt, wherein was entered the weight and the particulars of the metal and in case of old coins, their date and the mint of origin, used to be given to the owner. The bullion or silver, if unrefined, was handed over to the *gudazgar kham* (smelter of ore) to be refined and cast into ingots. The ingots were then handed over to the *waraqkush* (plate marker) who made plates of six mashas each measuring six fingers length and breadth. The plates were taken to the *gudazgar pukhta* who again melted them and cast them into ingots. If the metal brought to the mint was proved to have been refined already, the above process was not necessarily followed and the bullion or silver, having been brought directly to the melter of refined metal, was cast into ingots. The ingots were carried from the melter to the *zarrab* who cut them into round pieces of the size of coins. Then the round pieces were taken to the *sikkachi* who placed them one by one between two dies and stamped them. Such practice should have been followed in the southern mints of the Mughals. The details of the minting process described in *Ain-i-Akbari* are given in Appendix B.

The mint was housed in a walled enclosure where strict watch was kept at the gate, since utmost security was essential. At Surat, the mint house stood next to the customhouse[58].

Ain-i-Akbari puts the mint charges as follows: for 100 *Lal-i- Jalali* muhrs the charges were 5 muhrs 12 rupees and 3 ½ dams; for rupee (silver) 5%; for dams (copper) 5.85% of the net amount coined. Master writing in 1679 says that the charges of the mint amounted to about 6%.

Similar charges may have been levied at the southern mints.

CONCLUSION

Numismatists have started showing interest in the study of the Technology aspects of coinage. This is a good beginning. There is scope for further research specifically in the following areas.

1. Metallurgical and surface structure analysis of larger sections of the coinage - today the study is limited to certain dynasties and the preference of metals have been only the copper and the lead coins.
2. Metallurgical and surface structure analysis of the dies. This will throw light on the their production process.
3. Study of functioning of mints during ancient and medieval periods. Literary and historical sources can be the starting point, which can be further corroborated through archeological evidences.
4. Study of the sources of metals used in the coinage.

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APPENDIX A
Details of Dies Used in Travancore Mints[1]
All the dies are made of Iron (see Plate VIII)

Sl. No.	Symbol on the Die	Name of the coin minted	Ruler
40		Velli-chuckrums	Bala Rama Varma - I (A.D. 1798-1810)
41		Reverse of Velli-chuckrums	Bala Rama Varma - I (A.D. 1798-1810)
42		Obverse of copper cash	Marthanda Varma _II (A.D. 1847-1860)
43		Reverse of copper cash	Marthanda Varma _II (A.D. 1847-1860)
44		Velli-Fanam or R.V. Fanam	Rama Varma IV (A.D. 1860-1880)

[1] From Techniques Adopted in Travancore Mint by G. Sarojini Amma, SISC, VII.

Sl. No.	Symbol on the Die	Name of the coin minted	Ruler
45		Reverse of R.V. Fanam	Rama Varma IV (A.D. 1860-1880)
46	Chuckrum one ചക്രം ഒണ്	Obverse of one chuckrum	Rama Varma VI (A.D. 1885-1924)
47	Conch	Reverse of one chuckrum	Rama Varma VI (A.D. 1885-1924)
48	Cash Eight കാശ് എട്	Obverse of eight cash	Rama Varma VI (A.D. 1885-1924)
49	Conch	Reverse of eight cash R.V. Fanam	Rama Varma VI (A.D. 1885-1924)

APPENDIX B
EXTRACTS FROM AIN-I-AKBARI[2]

THE WORKMEN OF THE MINT

1. *The Dárógah*. He must be a circumspect and intelligent man, of broad principles, who takes the cumbrous burden of his colleagues upon the shoulder of despatch. He must keep every one to his work, and show zeal and integrity.

2. *The Sairafí*. The success of this important department depends upon his experience, as he determines the degrees of purity of the coins. On account of the prosperity of the present age, there are now numbers of skilful sarráfs; and by the attention of his Majesty, gold and silver are refined to the highest degree of purity. The highest degree of purity is called in Persia *dahdahí*, but they do not know above ten degrees of fineness; whilst in India it is called *bárahbání*, as they have twelve degrees. Formerly the old hun, which is a gold coin current in the Deccan, was thought to be pure, and reckoned at ten degrees; but his Majesty has now fixed it at 8½; and the round, small gold dínár of 'Aláuddín, which was considered to be 12 degrees, now turns out to be 10½.

Those who are experienced in this business have related wonderful stories of the purity of gold at the present time, and referred it to witchcraft and alchemy; for they maintain, that gold ore does not come up to this fineness. But by the attention of his Majesty, it has come up to this degree; hence the astonishment of people acquainted with this branch. It is, however, certain, that gold cannot be made finer, and of a higher degree. Honest describers and truthful travellers have indeed never mentioned this degree; but, when gold is put into fusion, small particles separate from it, and mix with the ashes, which ignorant men look upon as useless dross, whilst the skilful recover the metal from it. Although malleable gold ore be calcined and reduced to ashes, yet by a certain

[2] Ain-i-Akbari by Abul Fazl Allami. Translated by H. Blockhmann *etal*.

operation, it is brought back to its original state; but a part of it is lost. Through the wisdom of his Majesty, the real circumstances connected with this loss, were brought to light, and the fraudulent practices of the workmen thus put to the test.

BANWA´RI´

Although in this country clever Sairafis are able from experience to tell the degree of fineness by the colour and the brightness of the metal, the following admirable rule has been introduced, for the satisfaction of others.

To the ends of a few long needles, made of brass or such like metal, small pieces of gold are affixed, having their degree of fineness written on them. When the workmen wish to assay a new piece of gold, they first draw with it a few lines on a touchstone, and some other lines with the needles. By comparing both sets of lines, they discover the degree of fineness of the gold. It is, however, necessary that the lines be drawn in the same manner, and with the same force, so as to avoid deception.

To apply this rule, it is necessary to have gold of various degrees of fineness. This is obtained as follows. They melt together one máshah of pure silver with the same quantity of the best copper; and let it get solid. This mixture they again melt with 6 máshahs of pure gold of 10½ degrees of fineness. Of this composition one máshah is taken, and divided into sixteen parts of half a surkh each. If now 7½ surkhs of pure gold (of 10½ degrees) are mixed with one of the sixteen parts of the composition, the touch of the new mixture will only be 10¼ bán. Similarly, 7 surkhs pure gold and 2 parts of the composition melted together, will give gold of 10 bán; 6½ s. pure gold and 3 parts composition, 9¾ bán; 6 s. gold and 4 parts composition, 9½ bán; 5½ s. gold and 5 parts composition, 9¼ bán; 5 s. gold and 6 parts composition, 9 bán; 4½ s. gold and 7 parts composition, 8¾ bán; 4 s. gold and 8 parts composition, 8½ bán; 3½ s. gold and 9 parts composition, 8¼ bán; 3 s. gold and 10 parts composition, 8 bán; 2½ s. gold and 11 parts composition, 7¾ bán; 2 s. gold and 12

parts composition, 7½ bán; 1½ s. gold and 13 parts composition, 7¼ bán; 1 s. gold and 14 parts composition, 7 bán; and lastly, ½ s. gold and 15 parts composition, 6¾ bán. Or generally, every additional half surkh (or one part) of the composition diminishes the fineness of the gold by a quarter bán, the touch of the composition itself being 6½ bán.

If it be required to have a degree less than 6½ bán, they mix together ½ surkh of the first mixture which consisted, as I said, of silver and copper, with 7½ surkhs of the second composition (consisting of gold, copper and silver), which, when melted together, gives gold of 6¼ bán; and if 1 surkh of the first mixture be melted together with 7 surkhs of the second composition, the result will be 6 bán; and if they require still baser composi-tions, they increase the mixtures by half surkhs. But in the Banwárí, they reckon to 6 báns only, rejecting all baser compositions.

All this is performed by a man who understands the tests.

3. *The Amín.* He must possess impartiality and integrity, so that friends and enemies can be sure of him. Should there be any differences, he assists the dárógah and the other workmen, maintains that which is right, and prevents quarrels.

4. *The Mushrif.* He writes down the daily expenditure in an upright and practical manner, and keeps a systematic day-book.

5. *The Merchant.* He buys up gold, silver and copper, by which he gains a profit for himself, assists the department, and benefits the revenues of the State. Trade will flourish, when justice is everywhere to be had, and when rulers are not avaricious.

6. *The Treasurer* who watches over the profits, and is upright in all his dealings.

The salaries of the first four and the sixth officers differ from each other, the lowest of them holding the rank of an *Ahadí*.

7. The *Weighman*, who weighs the coins. For weighing 100 jaláli gold-muhurs, he gets 1¾ dáms; for weighing 1000 rupees, 6 19/25 dáms; and for weighing 1000 copper dáms, 11/25 of a dám; and, after this rate, according to the quantity.

8. *The Melter of the ore.* He makes small and large trenches in a tablet of clay which he besmears with grease, and pours into them the melted gold and silver, to cast them into ingots. In the case of copper, instead of using grease, it is sufficient to sprinkle ashes. For the above mentioned quantity of gold, he gets 2 3/5 dáms; for the same quantity of silver, 5 dáms and 13¼ jétals; for the same quantity of copper, 4 dáms and 21½ jétals.

9. *The Platemaker.* He makes the adulterated gold into plates of six or seven máshahs each, six fingers in length and breadth; these he carries to the assay master, 'who measures them in a mould made of copper, and stamps such as are suitable, in order to prevent alterations, and to shew the work done. He receives as wages for the above mentioned quantity of gold, 42 1/3 dáms.

THE MANNER OF REFINING GOLD

When the above-mentioned plates have been stamped, the owner of the gold, for the weight of every 100 jaláli goldmuhurs, must furnish 4 sérs of saltpetre, and 4 sérs of brickdust of raw bricks. The plates after having been washed in clean water, are stratified with the above mixture (of the saltpetre and brickdust), and put one above the other, the whole being covered with cowdung, which in Hindi is called *uplah*. It is the dry dung of the Wild Cow. Then they set fire to it, and let it gently burn, till the dung is reduced to ashes, when they leave it to cool; then these ashes being removed from the sides, are preserved. They are called in Persian *khák i khaláç*, and in Hindí

salóni. By a process to be mentioned hereafter, they recover silver from it. The plates, and the ashes below them, are left as they are. This process of setting fire to the dung, and removing the ashes at the sides, is twice repeated. When three fires have been applied, they call the plates *sitái*. They are then again washed in clean water, and stratified three times with the above mixture, the ashes of the sides being removed.

This operation must be repeated, till six mixtures and eighteen fires have been applied, when the plates are again washed. Then the assay master breaks one of them; and if there comes out a soft and mild sound, it is a sign of its being sufficiently pure; but if the sound is harsh, the plates must undergo three more fires. Then from each of the plates one máshah is taken away, of which aggregates a plate is made. This is tried on the touchstone; if it is not sufficiently fine, the gold has again to pass through one or two fires. In most cases, however, the desired effect is obtained by three or four fires.

The following method of assaying is also used. They take two tólahs of pure gold, and two tólahs of the gold, which passed through the fire, and make twenty plates of each, of equal weight. They then spread the above mixture, apply the fire, wash them, and weigh them with an exact balance. If both kinds are found to be equal in weight, it is a proof of pureness.

10. *The Melter of the refined metal*. He melts the refined plates of gold, and casts them, as described above, into ingots. His fee for 100 gold muhurs is three dáms.

11. *The Zarráb*. He cuts off the gold, silver and copper ingots, as exactly as he can, round pieces of the size of coined money. His fees are, for 100 gold muhurs, 21 dáms, 1¼ jétals; for the weight of 1000 rupees 53 dáms, 8¾ jétals, if he cuts rupees; and 28 dáms in addition, if he cuts the same weight of silver into quarter rupees. For 1000 copper dáms his fee is 20 dáms; for the same weight of half and quarter dáms, 25 dáms; and for half quarter dáms, which are called *dumrís*, 69 dáms.

In I´rán and Túrán they cannot cut these pieces without a proper anvil; but Hindustani workmen cut them without such an instrument, so exactly, that there is not the difference of a single hair, which is remarkable enough.

12. *The Engraver*. He engraves the dies of the coins on steel, and such like metals. Coins are then stamped with these dies. At this day, Mauláná 'Alí Ahmad of Delhi, who has not his equal in any country, cuts different kinds of letters in steel, in such a manner as equals the copyslips of the most skilful caligraphers. He holds the rank of a *yúzbáshí*; and two of his men serve in the mint. Both have a monthly salary of 600 dáms.

13. *The Sikkachí*. He places the round pieces of metal between two dies; and by the strength of the hammerer (*putkchí*) both sides are stamped. His fees are for 100 goldmuhurs, 1 2/5 dáms; for 1000 rupees, 5 dáms, 9½ jétals; and for the weight of 1000 rupees of small silver pieces, 1 dám, 3 jétals in addition; for 1000 copper dáms, 3 dáms; for 2000 half dáms, and 4000 quarter dáms, 3 dáms, 18¾ jétals; and for 8000 half-quarter dáms, 10½ dáms. Out of these fees the sikkachí has to give one-sixth to the hammerer, for whom there is no separate allowance.

14. *The Sabbák* makes the refined silver into round plates. For every 1000 rupees weight, he receives 54 dáms.
The discovery of alloy in silver. Silver may be alloyed with lead, tin and copper. In I´rán and Túrán, they also call the highest degree of fineness of silver *dahdahí*; in Hindustán, the sairafis use for it the term *bíst biswah*. Accord-ing to the quantity of the alloy, it descends in degree; but it is not made less than five, and no one would care for silver baser than ten degrees. Practical men can discover from the colour of the compound, which of the alloys is pre-vailing, whilst by filing and boring it, the quality of the inside is ascertained. They also try it by beating it when hot, and then throwing it into water, when blackness

denotes lead, redness copper, a white greyish colour tin, and whiteness a large proportion of silver.

THE METHOD OF REFINING SILVER

They dig a hole, and having sprinkled into it a small quantity of wild cow dung, they fill' it with the ashes of *Mughílan* wood; then they moisten it, and work it up into the shape of a dish; into this they put the adulterated silver, together with a proportionate quantity of lead. First, they put a fourth part of the lead on the top of the silver, and having surrounded the whole with coals, blow the fire with a pair of bellows, till the metals are melted, which operation is generally repeated four times. The proofs of the metal being pure are, a lightning-like bright-ness, and its beginning to harden at the sides. As soon as it is hardened in the middle, they sprinkle it with water, when flames resembling in shape the horns of wild goats, issue from it. It then forms itself into a dish, and is perfectly refined. If this dish be melted again, half a surkh in every tólah will burn away, i. e., 6 máshahs and 2 surkhs in 100 tólahs. The ashes of the dish, which are mixed with silver and lead, form a kind of litharge, called in Hindí *k'haral*, and in Persian *kúhnah*; the use of which will be hereafter explained. Before this refined silver is given over to the Zarráb, 5 máshahs and 5 surkhs are taken away for the Imperial exchequer out of every hundred tólahs of it; after which the assay master marks the mass with the usual stamp, that it may not be altered or exchanged.

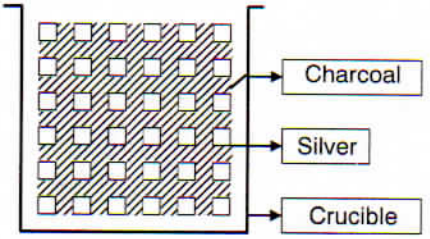
In former times silver also was assayed by the banwárí system; now it is calculated as follows:—if by refining 100 tolahs, of *sháhí* silver, which is current in 'Iráq and Khurásán, and of the *lárí* and *misqálí*, which are current in Túrán, there are lost three tólahs and one surkh; and of the same quantity of the European and Turkish *narjíl*, and the *mahmúdí* and *muzaffarí* of Gujrát and Málwah, 13 tólahs and 6½ máshahs are lost, they become of the imperial standard.

15. *The Qurçkúb* having heated the refined silver, hammers it till it has lost all smell of the lead. His fee for the weight of 1000 rupees, is 4½ dams.

16. *The Cháshnígír* examines the refined gold and silver, and fixes its purity as follows:—Having made two tólahs of the refined gold into eight plates, he applies layers of the mixture as above described, and sets fire to it, keeping out, however, all draught; he then washes the plates, and melts them. If they have not lost anything by this process, the gold is pure. The assay-master then tries it upon the touchstone, to satisfy himself and others. For assaying that quantity, he gets 1 2/5 dáms. In the case of silver, he takes one tólah with a like quantity of lead, which he puts together into a bone crucible, and keeps it on the fire till the lead is all burnt. Having then sprinkled the silver with water, he hammers it till it has lost all smell of the lead; and having melted it in a new crucible, he weighs it; and if it has lost in weight three *birinj* (rice grains), it is sufficiently pure; otherwise he melts it again, till it comes to that degree. For assaying that quantity, his fee is 3 dáms, 4½ jétals.

17. *The Niáriyah* collects the *khák i khaláç*, and washes it, taking two sérs at the time; whatever gold there may be amongst it, will settle, from its weight, to the bottom. The *khák*, when thus washed, is called in Hindí *kukrah*, and still contains some gold, for the recovery of which, directions shall hereafter be given. The abovementioned adulterated sediment is rubbed together with quicksilver, at the rate of six máshahs per sér. The quicksilver from its predilective affinity, draws the gold to itself, and forms an amalgam which is kept over the fire in a retort, till the gold is separated from the quicksilver.

For extracting the gold from this quantity of *khák*, the *Niyáriyah* receives 20 dáms, 2 jétals.



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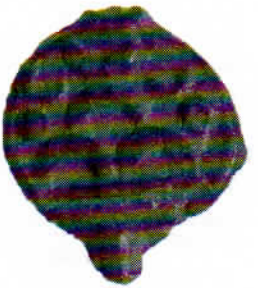

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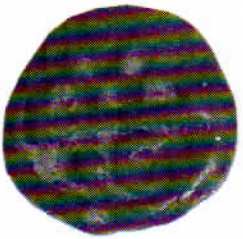

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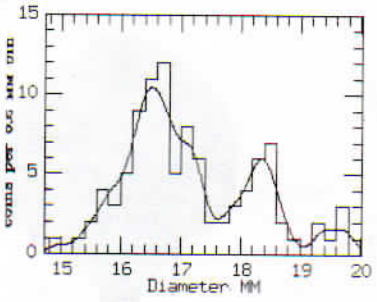
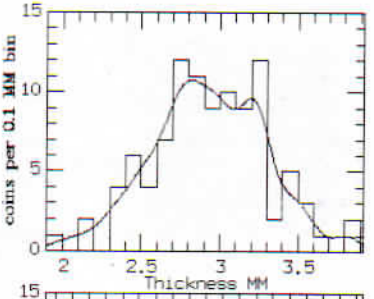
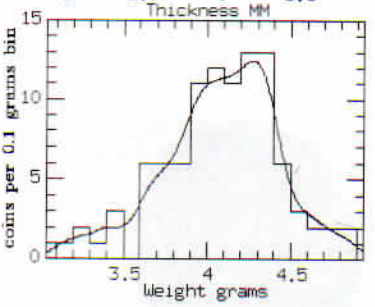
PLATE - I







RajaRaja Chola Copper Massa
Diameter - Thickness - Weight
Distributions of 100 Coins

Subset	smaller	larger
Number coins	69	31
Diameter MM	16.54(0.54)	18.53(0.58)
Thickness MM	3.06(0.32)	2.65(0.28)
Weight grams	4.08(0.36)	4.09(0.31)

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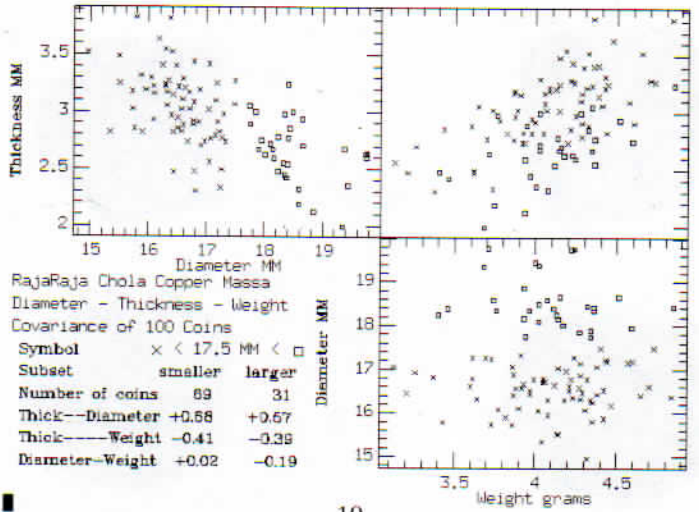

RajaRaja Chola Copper Massa
Diameter - Thickness - Weight
Covariance of 100 Coins

Symbol × < 17.5 MM < □

Subset	smaller	larger
Number of coins	69	31
Thick--Diameter	+0.58	+0.67
Thick-----Weight	-0.41	-0.39
Diameter-Weight	+0.02	-0.19

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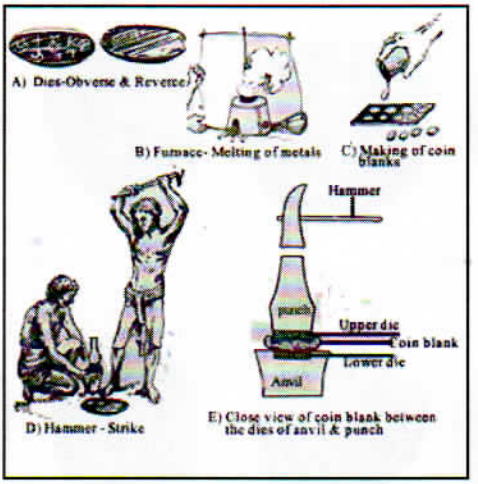
PLATE - II



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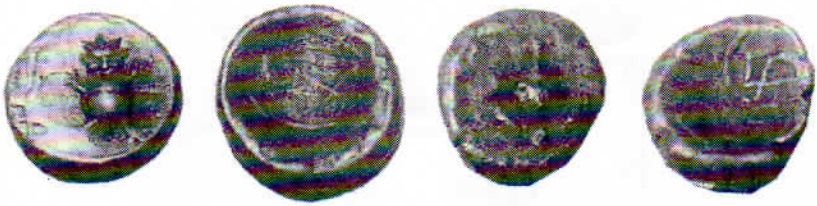

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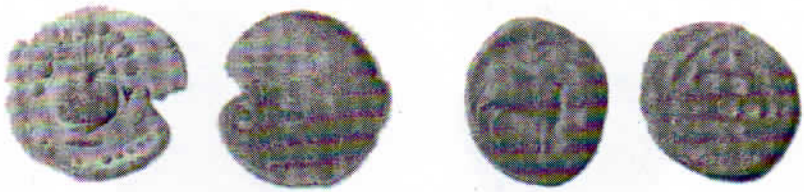

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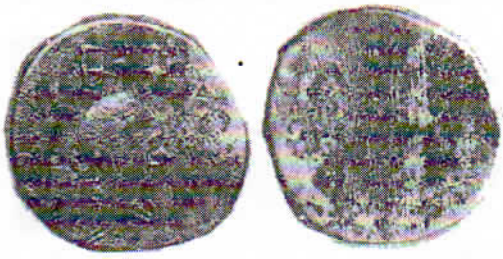

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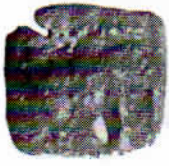

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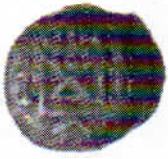

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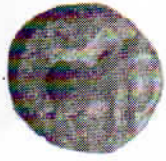

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PLATE - V

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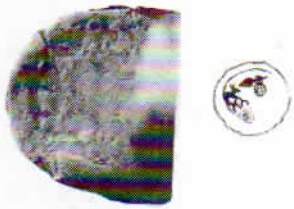

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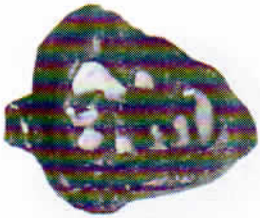

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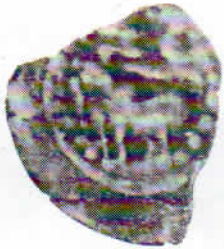

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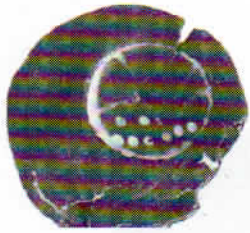

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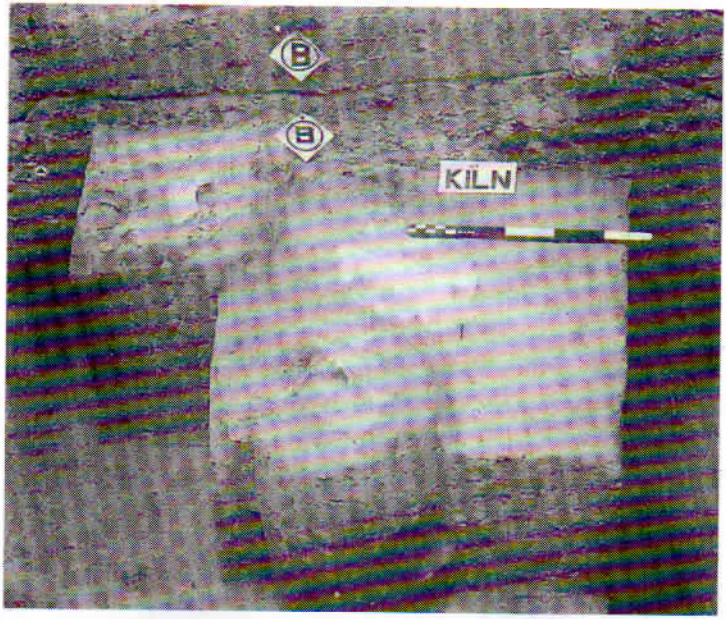
PLATE - VI



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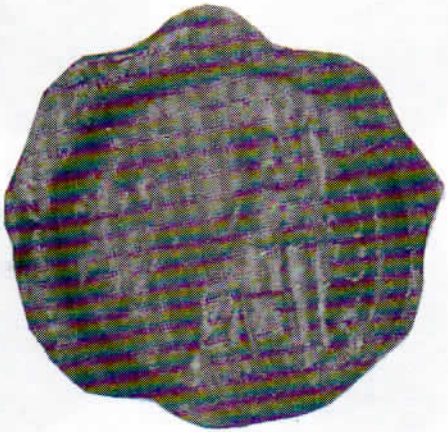

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PLATE - VII

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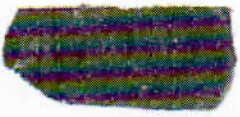

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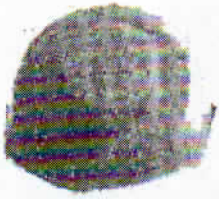

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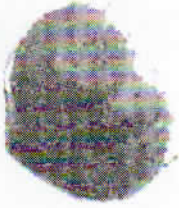

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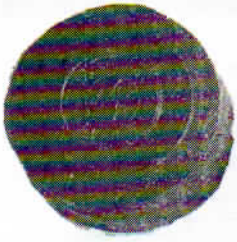

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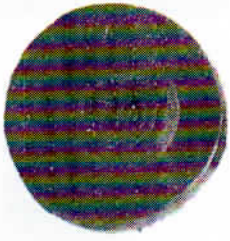

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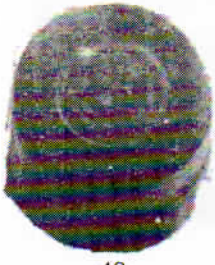

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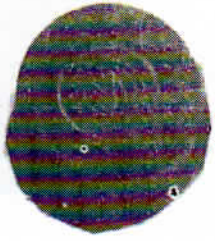

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PLATE - VIII